



## **Elbil - scenarier for dansk vejtransport : Energi, CO2 emission og økonomi?**

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# El til Vej-transport

## Fleksible El-systemer og Vindkraft

WORKSHOP

8. marts 2011 kl. 13.30 - 16.30 hos Dansk Energi

## Elbil - scenarier for dansk vejtransport:

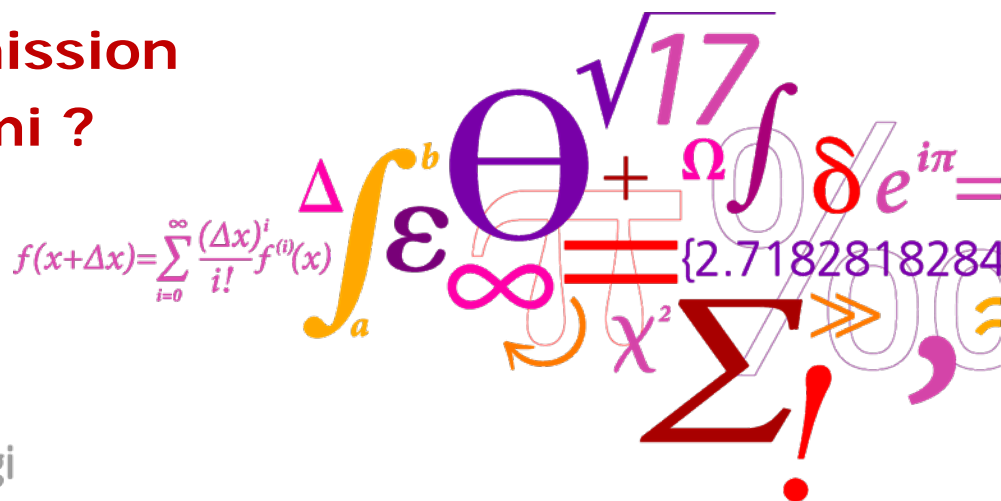
**Energi**

**CO<sub>2</sub> emission**

**økonomi ?**

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SYS Risø DTU

**Risø DTU**  
Nationallaboratoriet for Bæredygtig Energi



# Content

The project in short.

## **EV- technology & EV- scenarios**

- **Energy substitution**
- **CO<sub>2</sub> emission consequences**
- **Socio-economy / cost of ownership  
(marginal partial analyses)**

## **Some conclusions**

Basis for further analyses on

- overall power system aspects
- power transmission aspects
- power distribution aspects

The Project:

## **El til Vejtransport, Fleksible El-systemer og Vindkraft.**

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Deltagere:

**Forskningscenter Risø, DTU: SYS, VEA**

**ØRSTED, DTU: CET**

**RAM-løse edb**

**EnergiNet.dk**

**Dansk Energi**

Overordnet mål:

Analyse af **mulige samspil** mellem

- **el- og kraftvarmesektoren og**
- **transportsektoren,**

dersom dele af vej-transporten baseres

- **'plug in' hybrid- og/eller elbil-teknologi.**

# Content

## 1) EV- technology (assumptions)

- Energy substitution
- CO<sub>2</sub> emission consequences
- Socio-economy / cost of ownership  
(marginal partial analyses)

## 2) EV- scenarios (based on EPRI scenario)

## Some conclusions

## Vehicles: Passenger cars and LDV < 3.5 ton

The expected '**close to average**' **fleet** passenger vehicles defined in versions of:

**Reference:** Internal Combustion Engine Vehicle (**ICEV**)

**Alternative:** Hybrid Electric Vehicle (**HEV**)  
 Plug-In Hybrid Electric Vehicle (**PHEV**)  
 Battery Electric Vehicle (**BEV**) (All-electric)

### Vehicle data:

**Ref.: COWI (2007), EPRI (2007), IEA (2009), DOE (2010)**

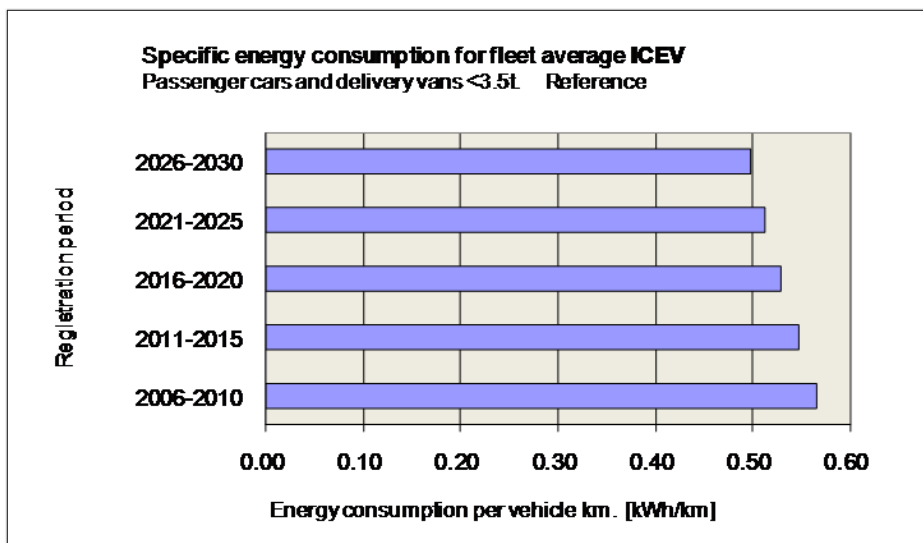
# Links assumed:

(among defined fleet average vehicles)

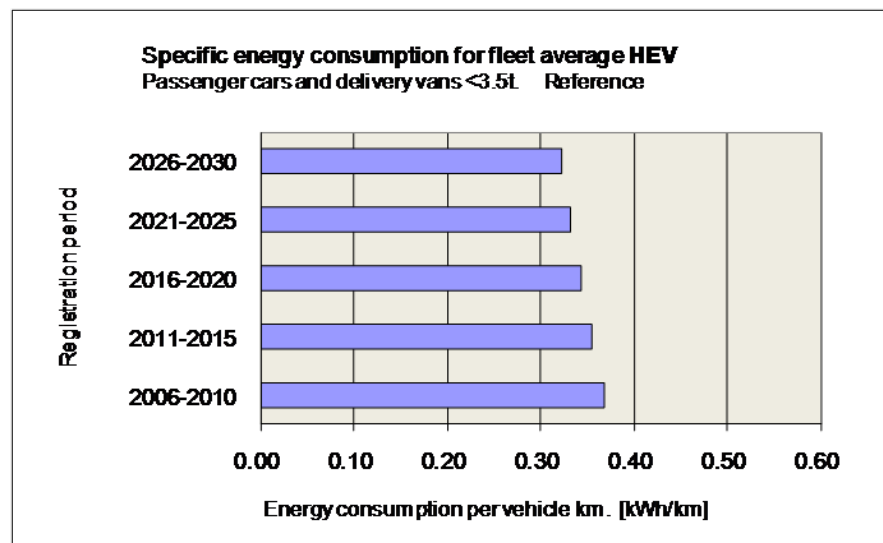
- **PHEVs operated in HEV-mode** have the same specific energy (gasoline/diesel) consumption **as the defined HEV vehicle**.
- **PHEVs operated in BEV-mode** (or charge depletion mode) have the same specific energy consumption (electricity) **as the defined BEV vehicle**.
- **HEV fuel consumption equal to 65%** of the ICEV within a vintage group.

# Vehicle energy consumption: kWh/km

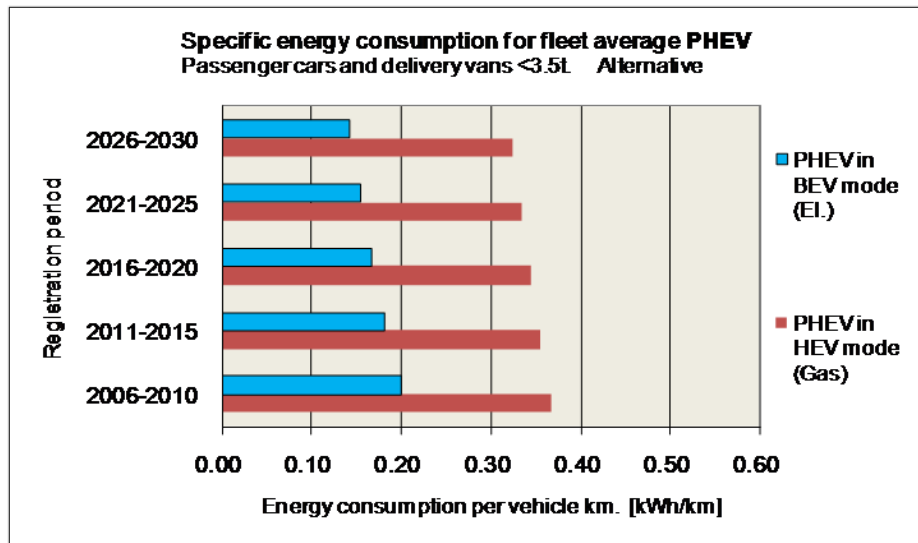
## ICEV fuel consumption:



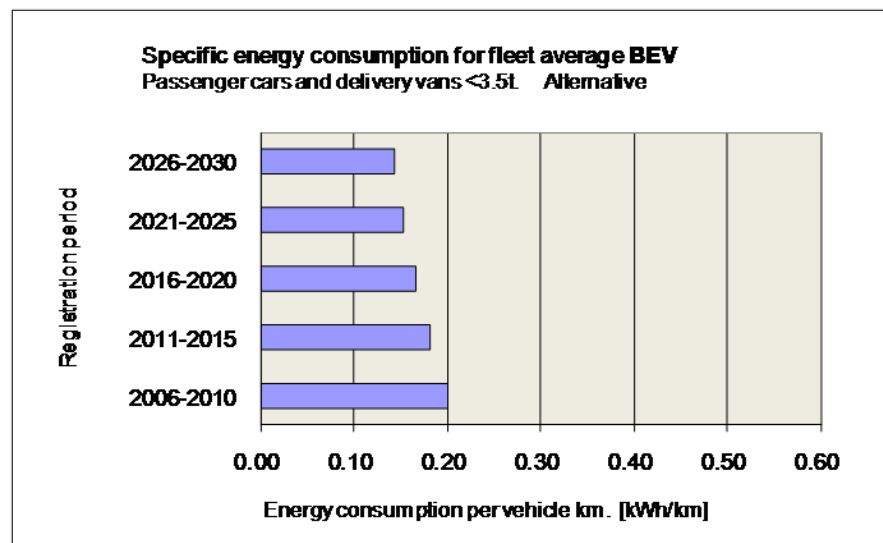
## HEV fuel consumption:



## PHEV electricity and fuel consumption:

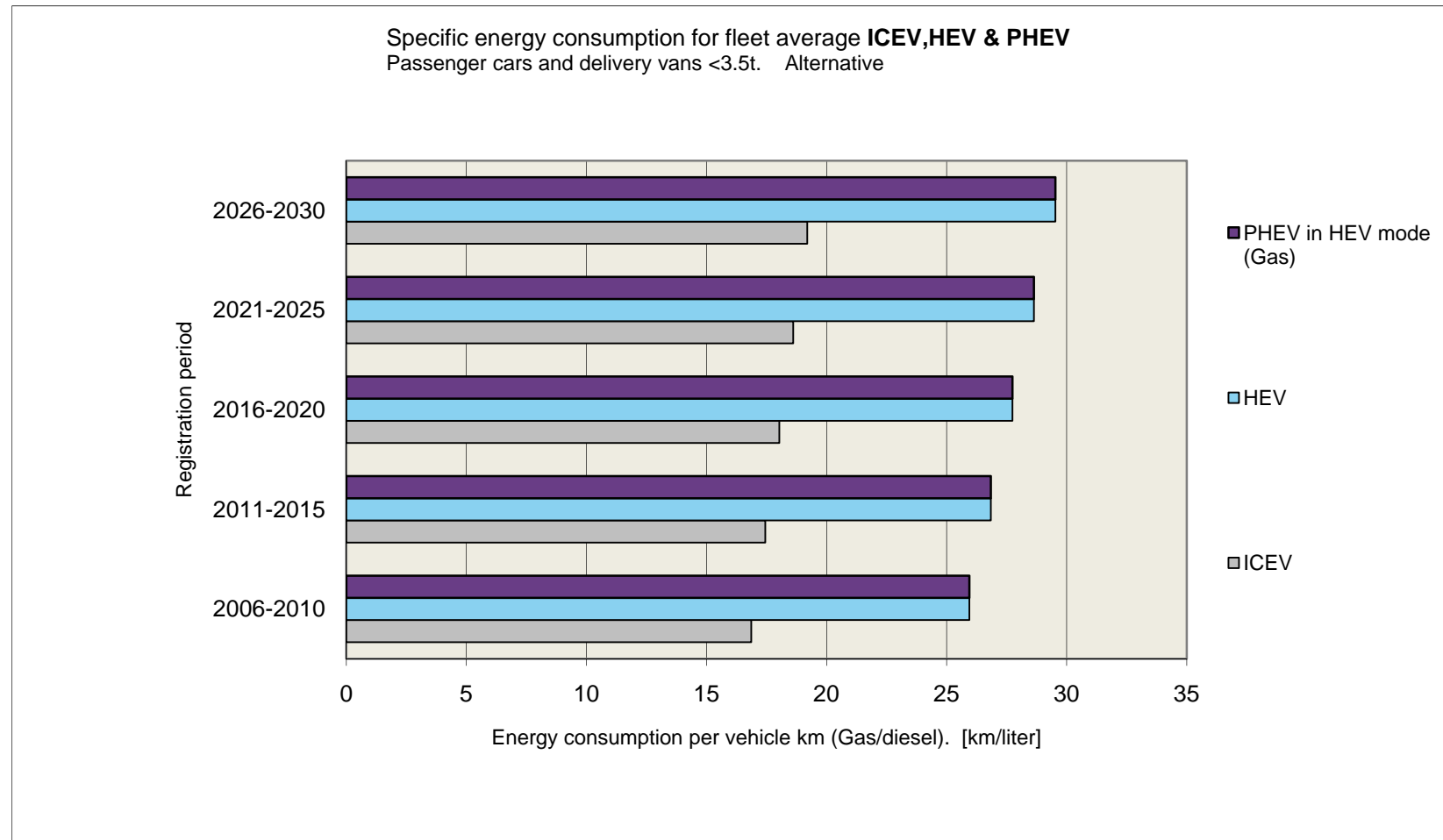


## BEV electricity consumption:





# Vehicle energy consumption: km/liter

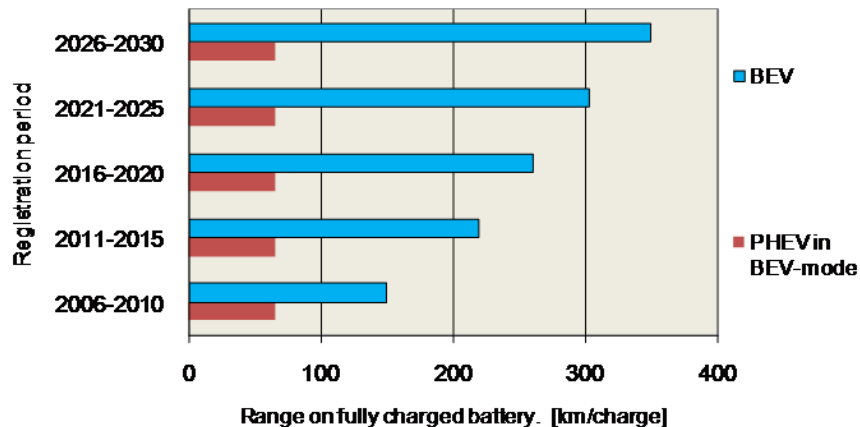


# Electric Vehicle:

## Battery size and range per charge

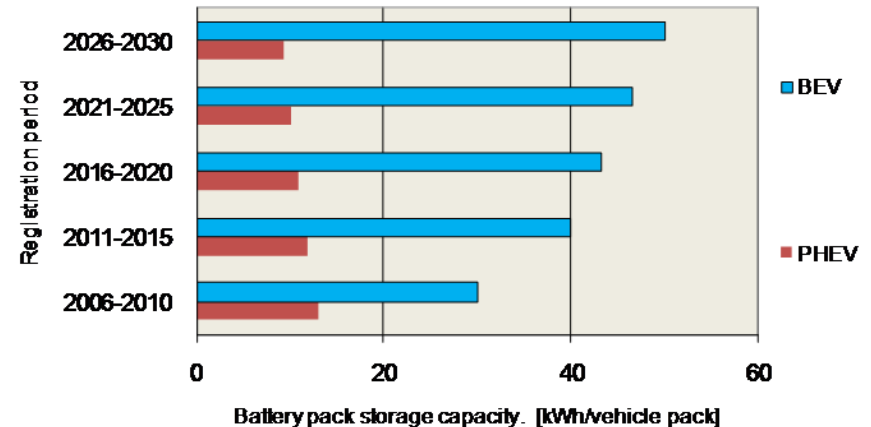
PHEV & BEV: Range [km/charge]

Range per charge for fleet average: BEV and PHEV  
Passenger cars and delivery vans <3.5t Alternative



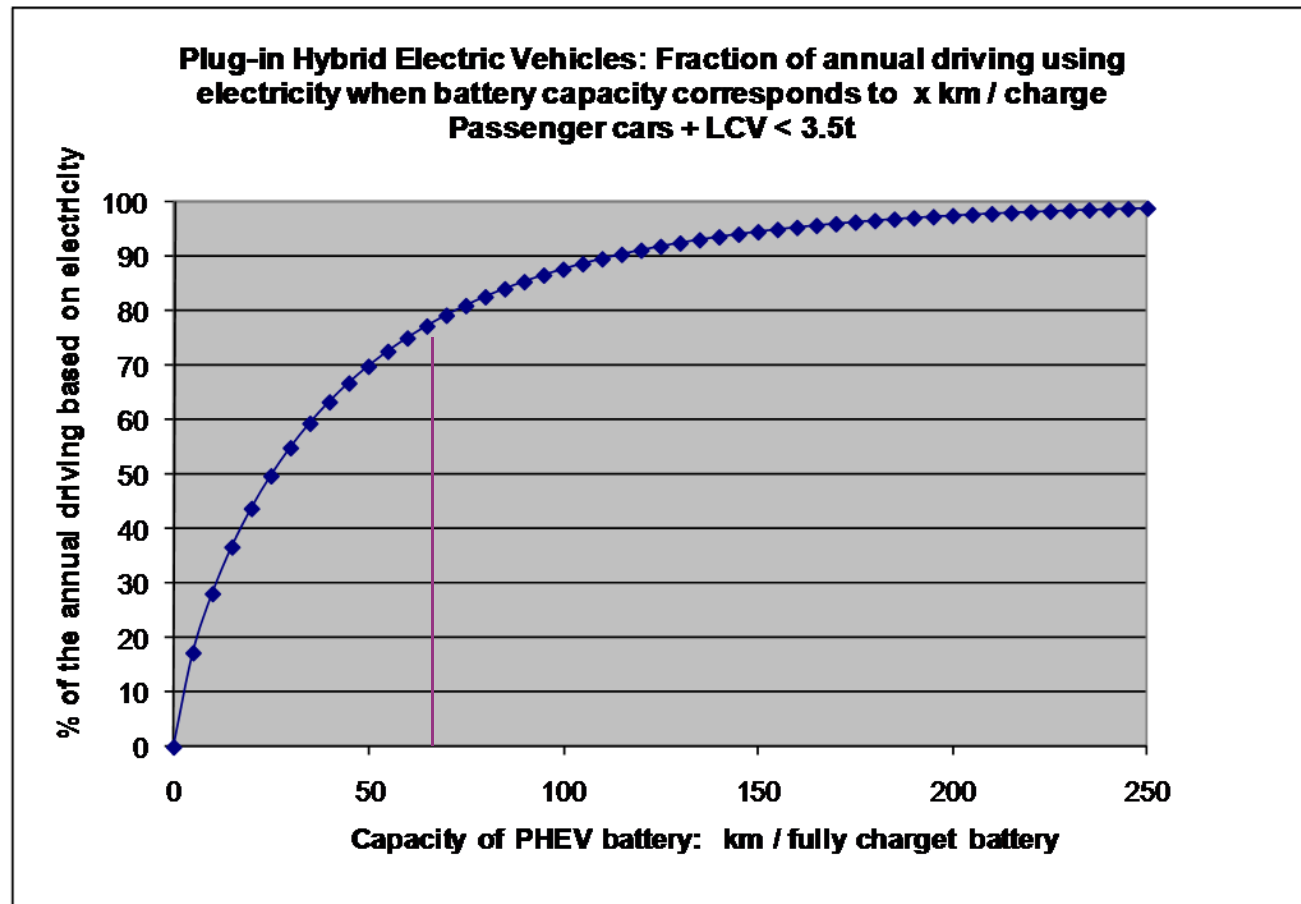
PHEV & BEV: Battery size [kWh/pack]

Battery storage capacity in kWh/vehicle: BEV and PHEV  
Passenger cars and delivery vans <3.5t Alternative



# Plug-in Hybrid Electric Vehicles (PHEV):

## % of annual driving on electricity in DK ?

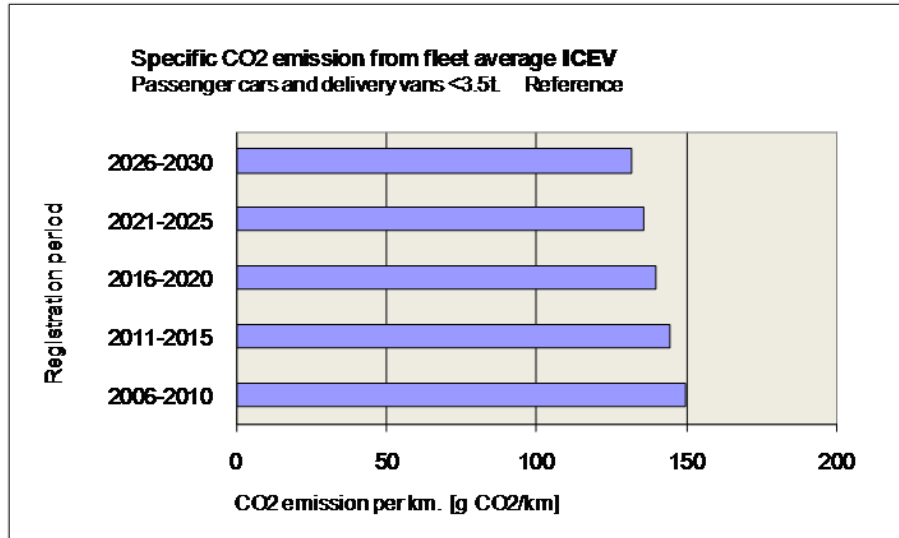


Source: Estimated (Weibull) distribution based on data from DTU Transport: 'Transport Vane Undersøgelse: 2006+2007'.

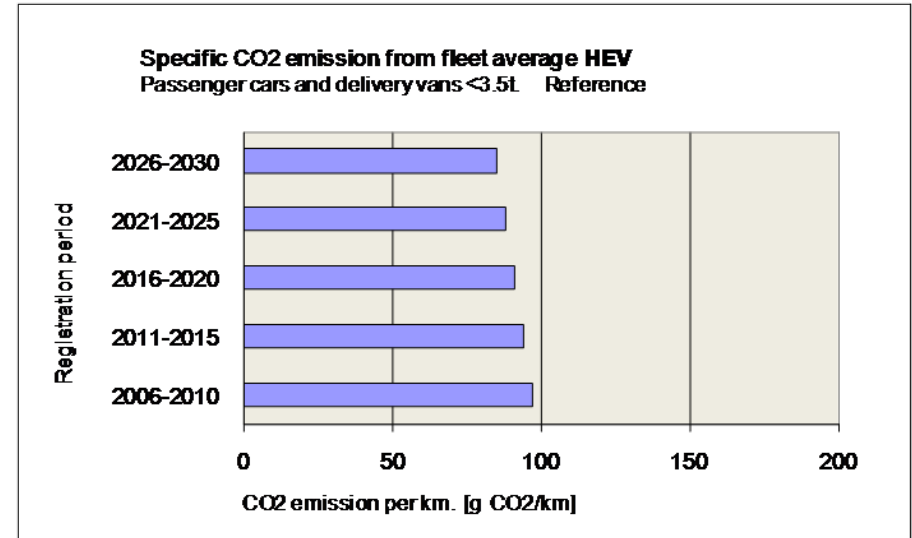
# Vehicle specific CO<sub>2</sub> emission: g CO<sub>2</sub> /km

**CO<sub>2</sub>Case I : Marginal el-production in DK (coal)** Source: DEA (2010)

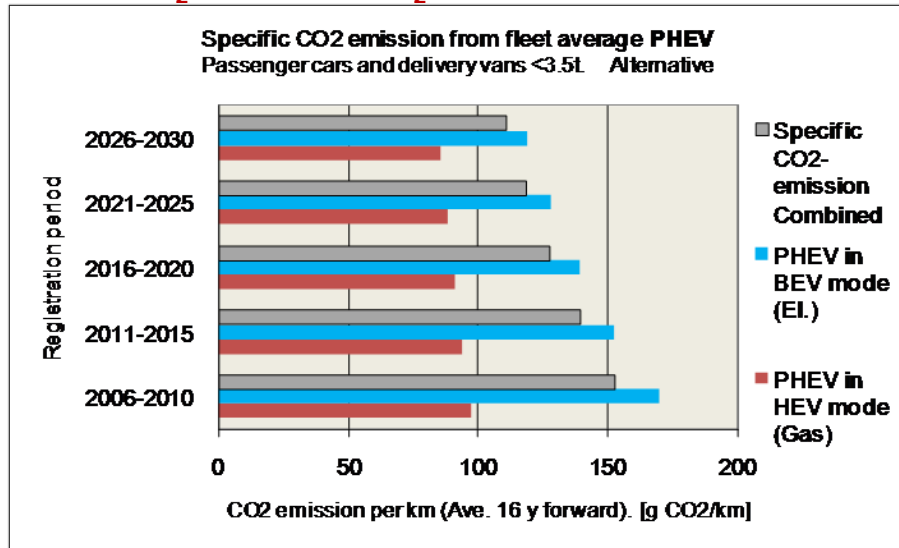
**ICEV CO<sub>2</sub> emission:**



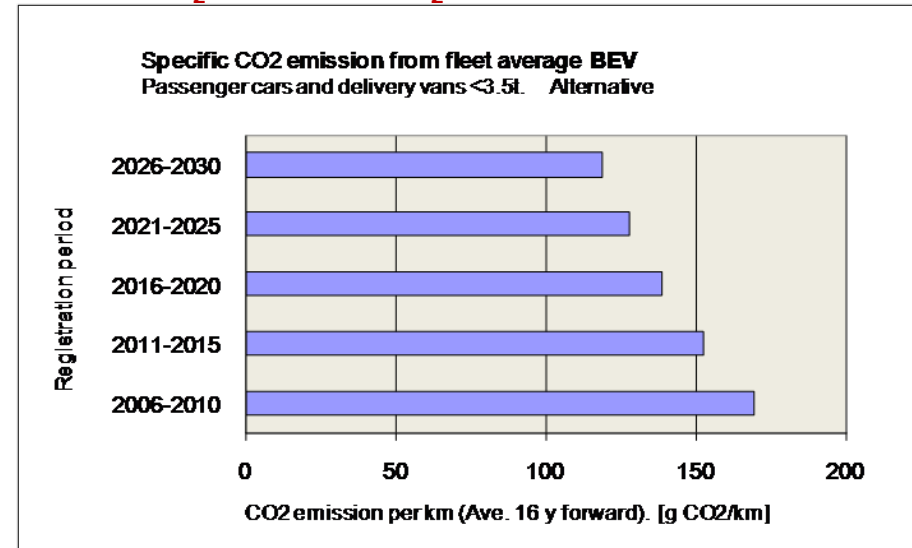
**HEV CO<sub>2</sub> emission:**



**PHEV CO<sub>2</sub> emission: CO<sub>2</sub>Case I**



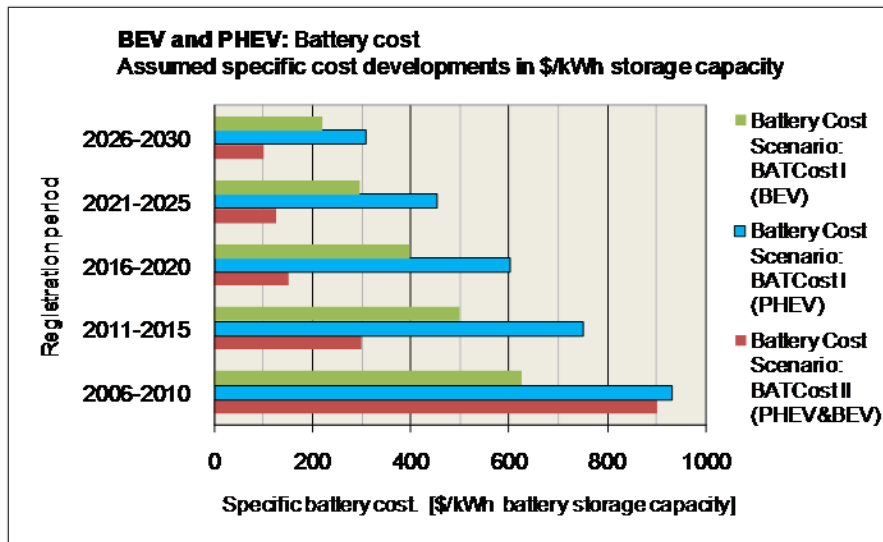
**BEV CO<sub>2</sub> emission: CO<sub>2</sub>Case I**



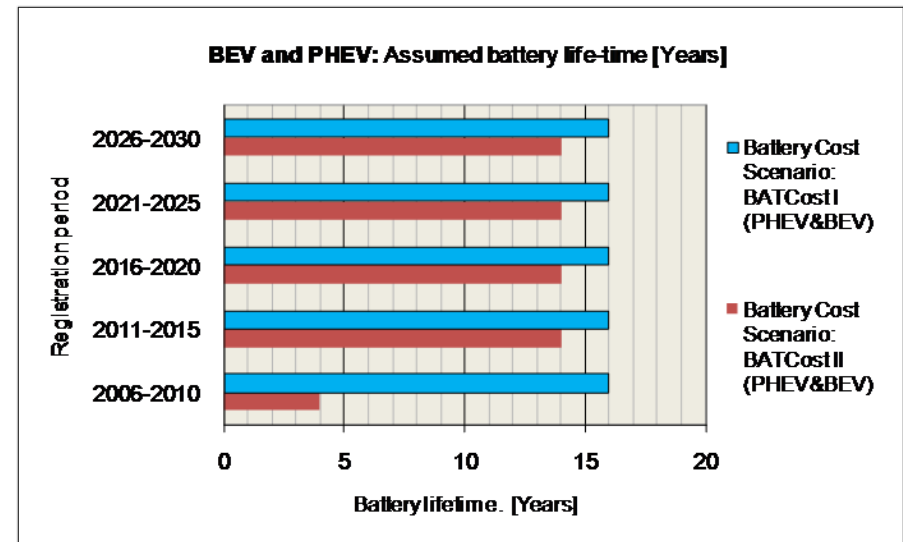
# Electric Vehicle: PHEV and BEV

## Battery cost and lifetime

Cost: \$/kWh battery



Lifetime: Years



### Assumptions:

**BatCost I :** EV battery cost development scenario based on ref.: COWI (2007) & IEA (2009)

**BatCost II:** EV battery cost development scenario based on ref.: USDOE, The Recovery Act : Transforming America's Transportation Sector, Batteries and Electric Vehicles, July 14, 2010.

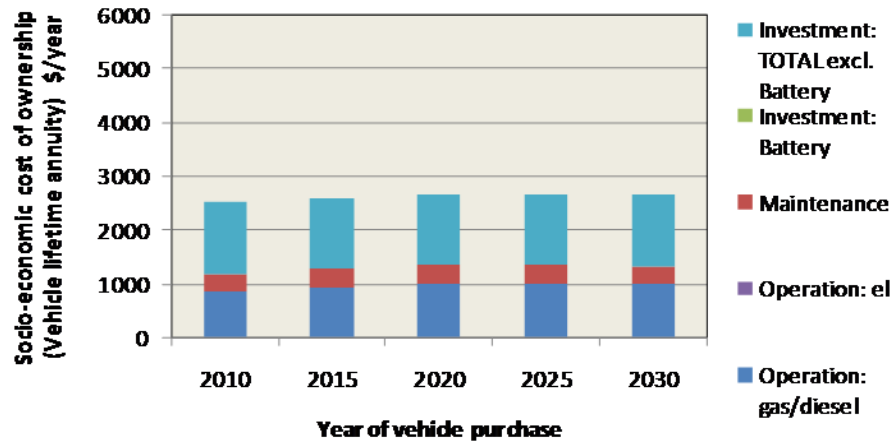
# Vehicle cost of ownership: \$/year

EV battery cost: USDOE July 2010 Scenario



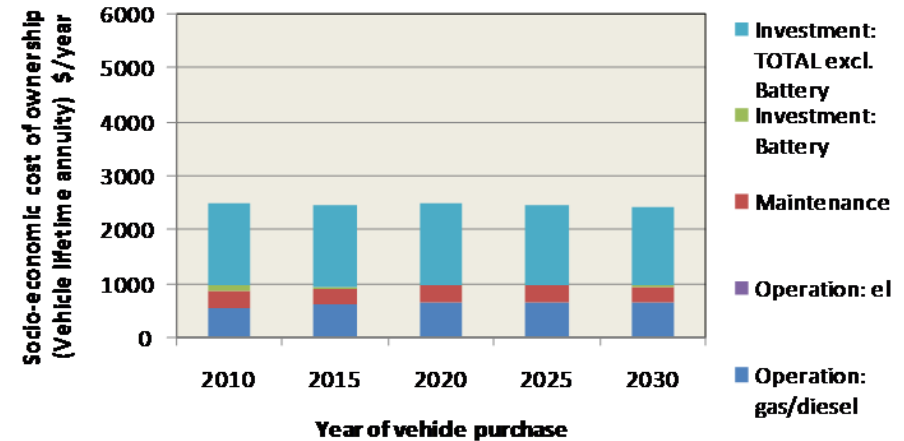
ICEV:

Socio-economic cost of ownership: ICEV Reference



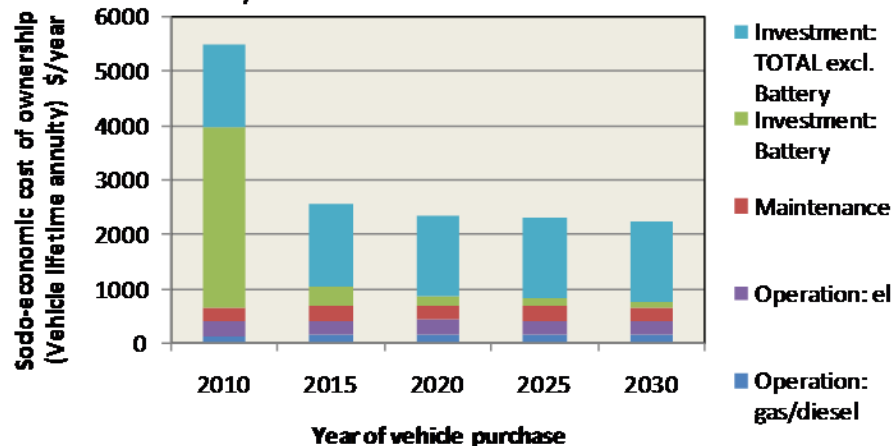
HEV:

Socio-economic cost of ownership: HEV Alternative



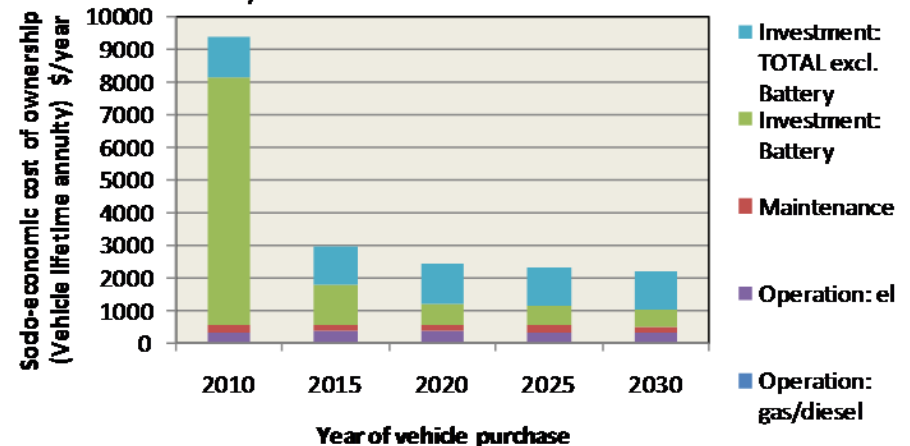
PHEV: BatCost II, US DOE 2010 scenario

Socio-economic cost of ownership: PHEV Alternative  
Battery cost data: BATCost II



BEV: BatCost II, US DOE 2010 Scenario

Socio-economic cost of ownership: BEV Alternative  
Battery cost data: BATCost II

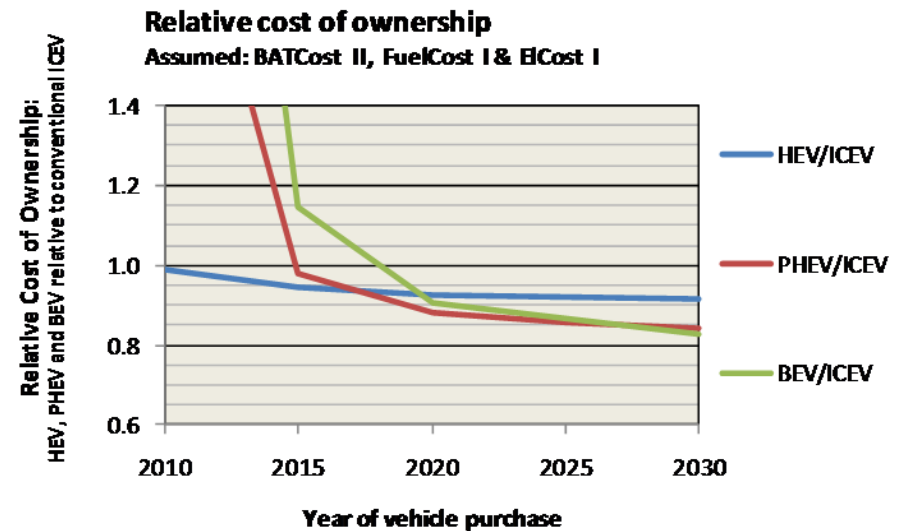
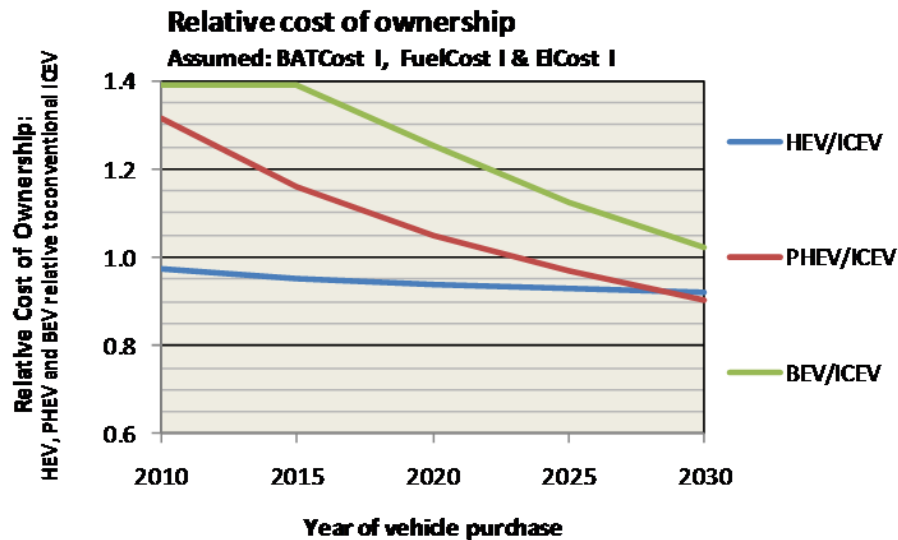


**Relative cost of ownership:**  $(\$/\text{year}) / (\$/\text{year})$

**BEV, PHEV, HEV / ICEV**

**BatCost I : DK DEA 2010 scenario**

**BatCost II: US DOE 2010 Scenario**



# Conclusion: Individual EVs

## Energy & CO<sub>2</sub> emission

### Energy:

- **Electricity substitutes gasoline/diesel** via the EV.
- **EV drive trains** have potential for being very **energy efficient**.
- 3000 kWh electricity may sustain about 20.000 km average vehicle driving.
- Via EVs segments of the transport sector can **diversify its energy resource base** and reduce dependency on oil based fuels.

### CO<sub>2</sub> emission:

- **EV CO<sub>2</sub> emission relates to the power supply** system charging the vehicles. The EV footprint of the individual vehicle change in accordance with the power supply.
- According to the Danish 'reference' development for the marginal power supply EVs bring almost **insignificant CO<sub>2</sub> reduction (due to coal dominated marginal power production)**. However, assuming linear descend to zero CO<sub>2</sub> emission in 2050 for the power supply substantial CO<sub>2</sub> reduction is achieved via EVs substituting ICEVs. Ultimately EVs may provide zero CO<sub>2</sub> emission road transport.
- The individual ICEV of today may emit **about 2-3 ton CO<sub>2</sub> /year. This equals max achievable EV CO<sub>2</sub> reduction.**



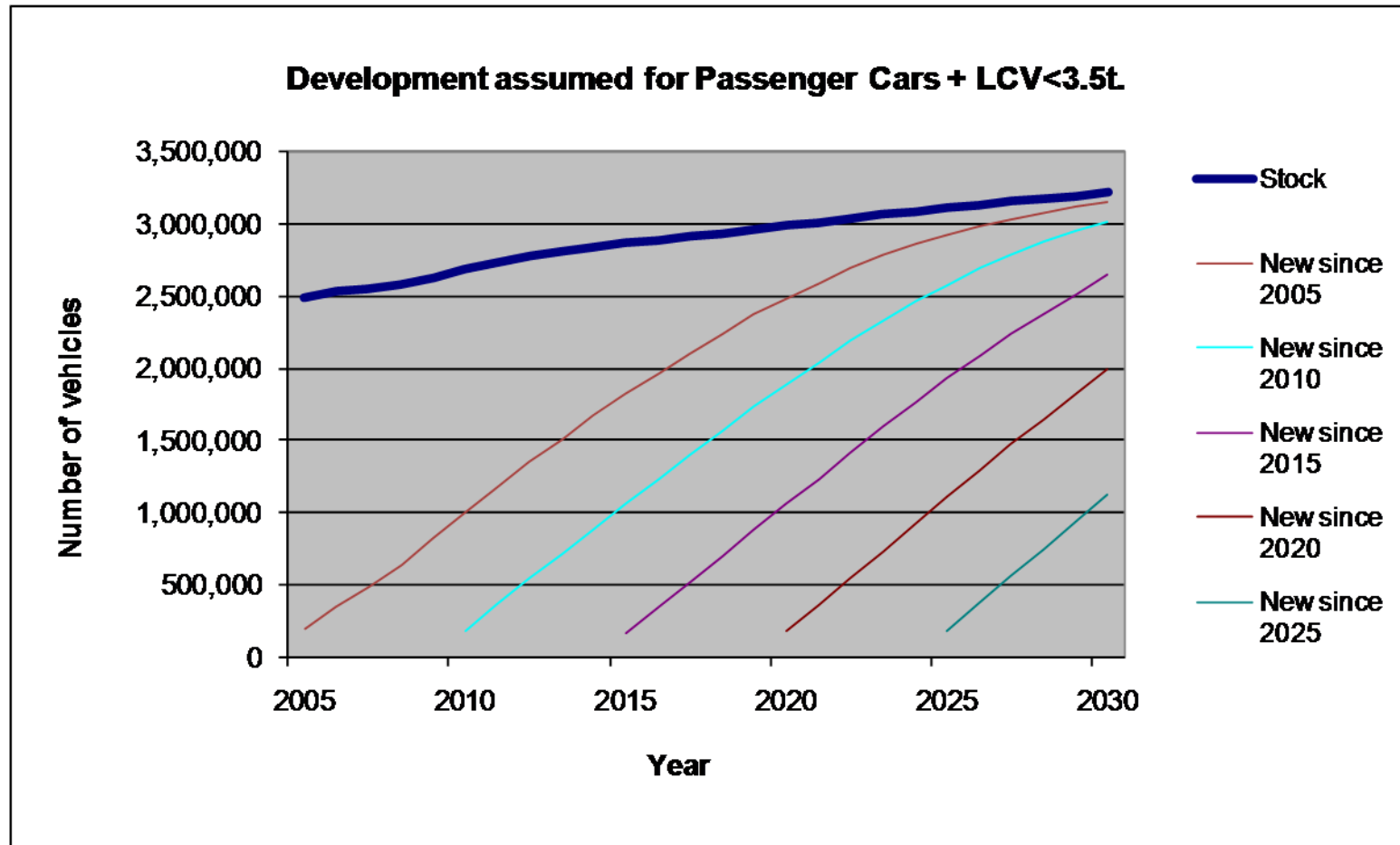
# Conclusion: Individual EVs

## Economy:

- Cost and lifetime of **EV batteries much determine the EV economy**. Based on (marginal and partial) socio-economic costs of ownership.
- In 'reference' battery cost development **PHEVs may get break-even with the ICEV beyond year 2020**.
- In 'alternative' battery cost development **PHEVs may get break-even with the ICEV year 2015**.
- CO<sub>2</sub> emission allowance **costs of 2-3 ton CO<sub>2</sub> are small put relative to costs of vehicle ownership**. May not constitute incentive for vehicle purchase.

# Danish fleet: Vehicle/fleet renewal

Segment: Passenger Cars + LDV < 3.5t



Danish fleet:

**PHEV Scenario:**

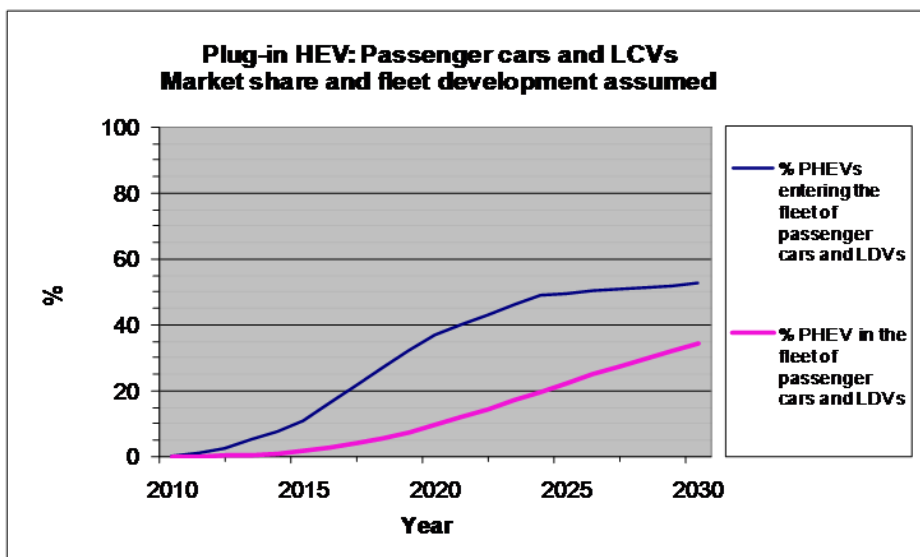
**Market share & fleet development**

(# PHEVs)

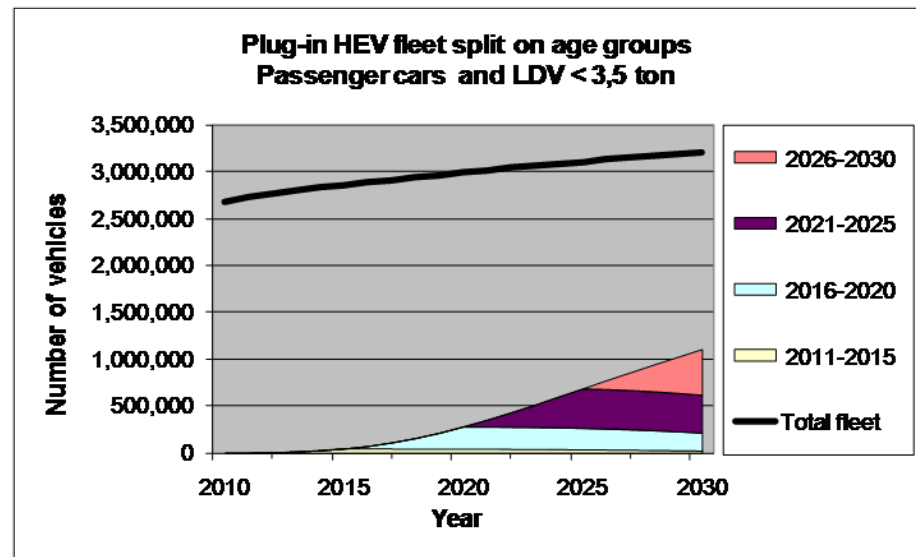
Segment: Passenger Cars + LDV < 3.5t



## PHEV Market share



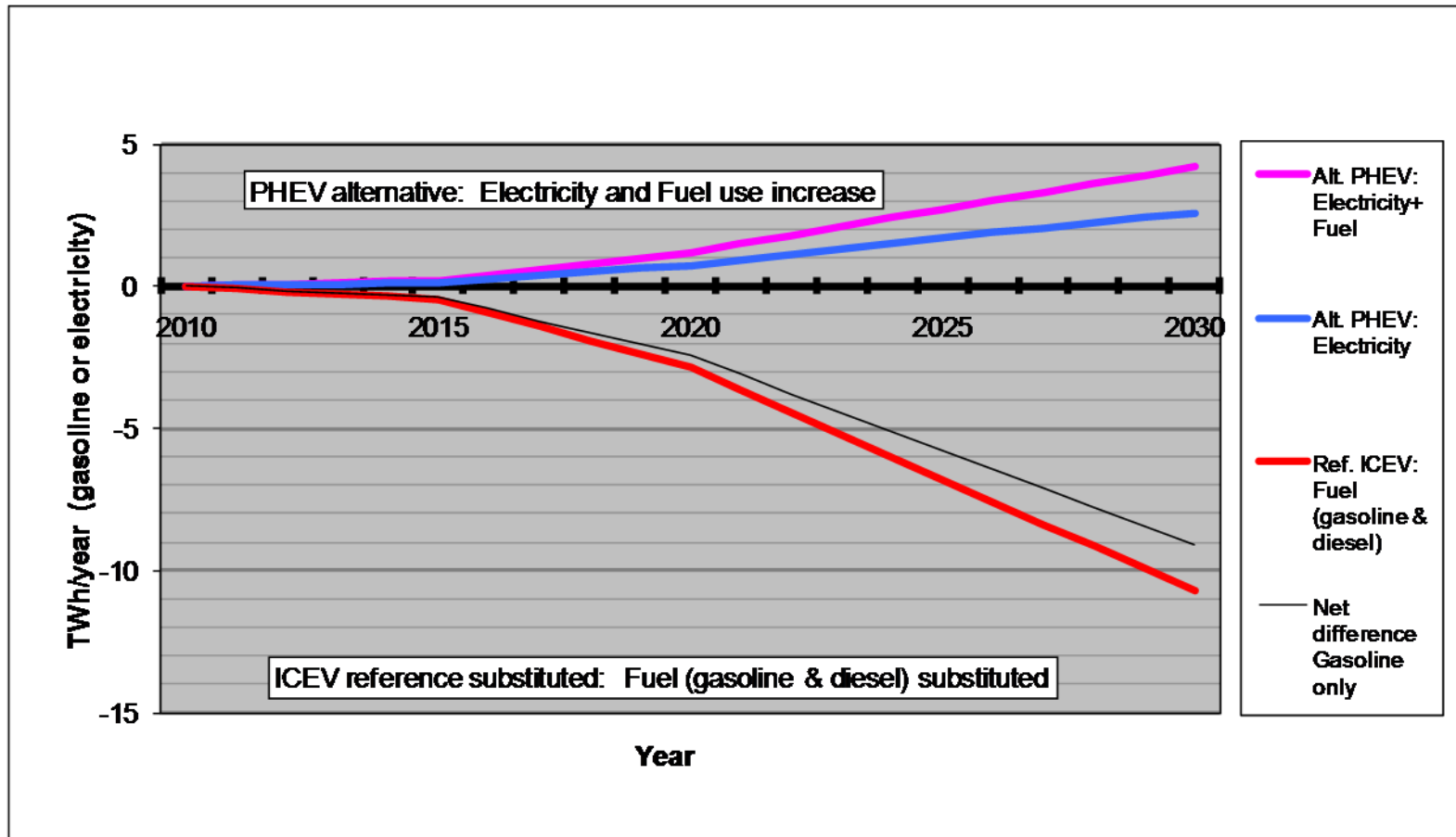
## PHEV: Fleet development



# Danish fleet: PHEV Scenario: Energy substitution

(TWh/year (fuel or el.))

Segment: Passenger Cars + LDV < 3.5t

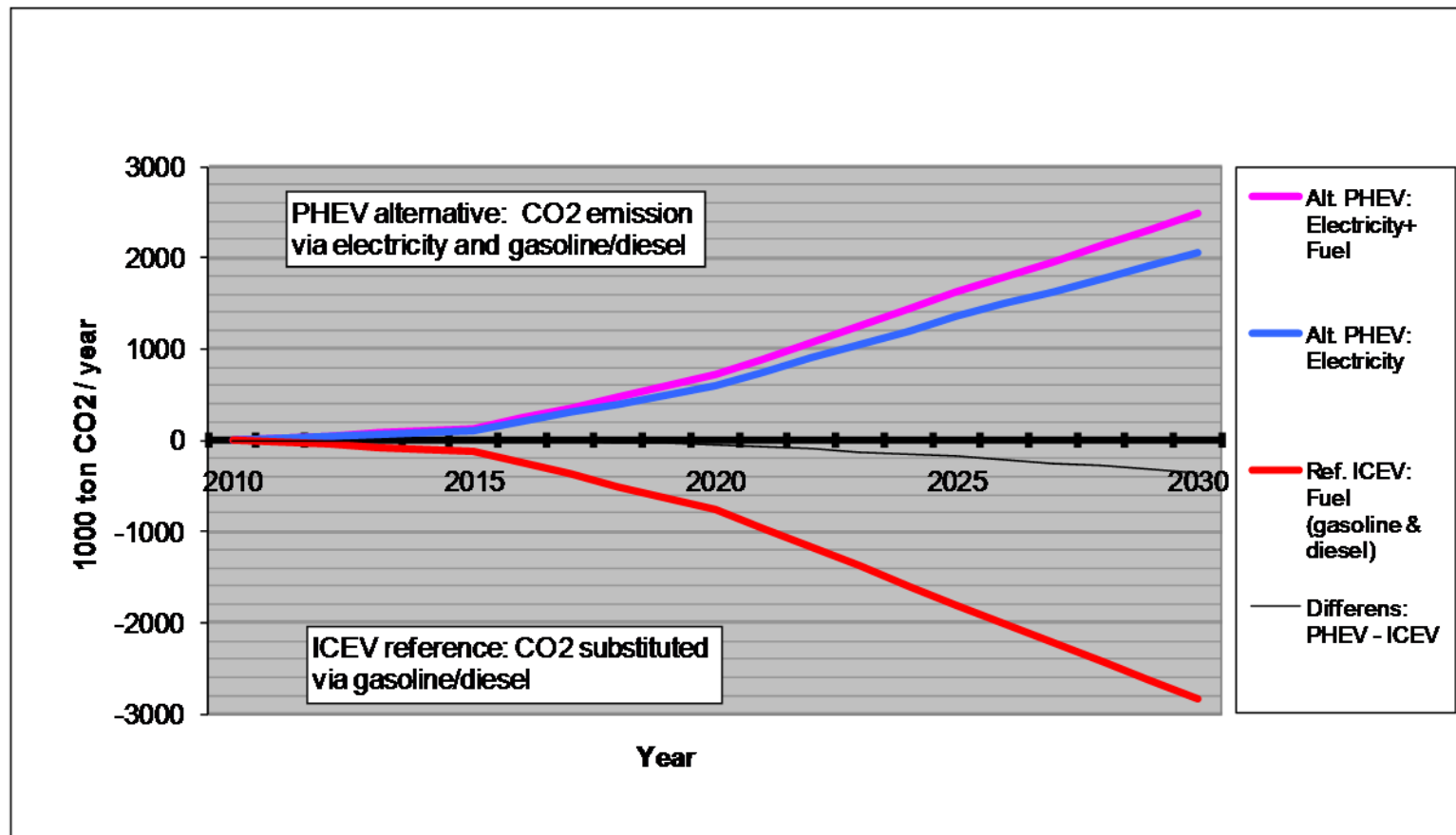


# Danish fleet: PHEV Scenario: CO<sub>2</sub> emission

(1000 ton CO<sub>2</sub> /year)

Segment: Passenger Cars + LDV < 3.5t

**CO<sub>2</sub>Case I** : Marginal (coal based) power supply (DK DEA 2010)



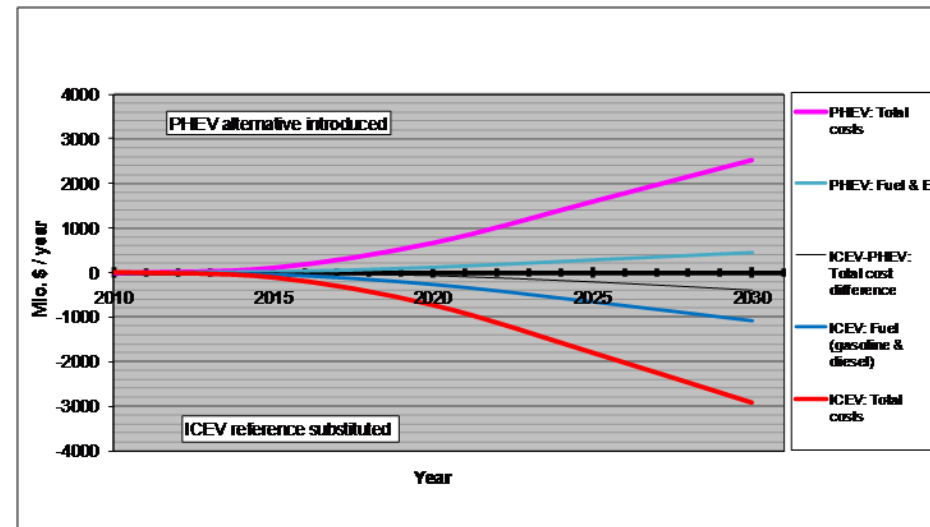
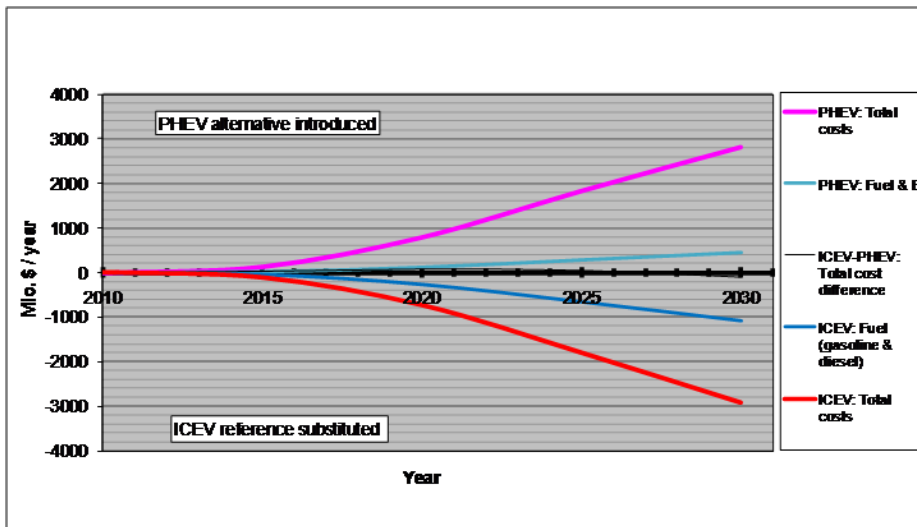
Danish fleet:

**PHEV Scenario:**

**Socio-economic costs of ownership** (Mio.\$ /year)  
(marginal & partial analysis)

BatCost I : **Reference**

BatCost II : **US DOE 2010**



# Conclusion: **PHEV (& BEV) scenario**



## Energy & CO<sub>2</sub> emission

### Energy:

- **Electricity substitutes gasoline/diesel** via the PHEV and BEV scenarios.  
Focusing on year 2030:
  - PHEV scenario year 2030:
    - ICEV** Fuel (gasoline/diesel) substituted: - **About 9.0 TWh<sub>fuel</sub> /year**
    - PHEV** fleet electricity consumption: + **About 2.5 TWh electricity**
  - BEV scenario year 2030:
    - Fuel (gasoline/diesel) substituted: About 5.4 TWh<sub>fuel</sub> /year.
    - Corresponding BEV fleet electricity consumption: About 1.7 TWh electricity.
- EVs in the transport sector can **diversify energy resource base** and **reduce dependency on oil** based fuels.

### CO<sub>2</sub> emission:

- The EV scenario CO<sub>2</sub> emission **depends on the power supply system** charging the EV fleet.

# Conclusion: **PHEV (& BEV) scenario**



**Economy:**      **Based on (marginal and partial) socio-economic analysis.**

## **Economy:**

- Cost and lifetime of **EV batteries much determine the EV economy** and outcome of the PHEV and BEV scenarios.
- In a **'reference' battery cost** development the **PHEV** scenario is close to break-even with reference development. **Beyond year 2025 annual socio-economic gains emerge.**

The BEV scenario, however, show annual deficits throughout the period, though relatively smaller later in the period.

- In an **'alternative' battery cost** development (US DOE 2010) the **PHEV scenario is attractive from year 2015** and throughout the period. The BEV scenario becomes cost effective from beyond year 2020.
- CO<sub>2</sub> emission **allowance costs are small** put relative to costs of vehicle ownership and the scenario costs.